Spatial and temporal trends of precipitation and temperature for the MPUAT service area, Rajasthan, India

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Abstract: *The present study focuses on the long term trends of meteorological parameters like precipitation and temperature of the MPUAT service area, Rajasthan, India which is mainly located in humid and sub-humid region. Trend analysis of the seasonal (pre-monsoon, monsoon, post-monsoon and winter) and annual daily rainfall and temperature at the spatial and temporal scales was carried out for 7 stations of the MPUAT, service area. Statistical trend analysis technique, namely the Mann–Kendall test, was used to examine trends (1984–2014) at the 5% level of significance. Both positive and negative trends were observed in both seasonal and annual events of rainfall and temperature.The spatial variations of the trends in seasonal (pre-monsoon, monsoon, post-monsoon and winter) and annual daily rainfall and temperature were also determined using the inverse-distance-weighted (IDW) interpolation technique. IDW results are helpful to identify trends and variability in seasonal and annual rainfall and temperature in space and time for the study locations where the data is not available and the quality of data is not good. These spatial maps of temperature and rainfall can aid in designing the effective water resources planning over the MPUAT service area under climate change.*

I. Introduction

Climate change is becoming the hottest topic to the entire globe. Climate may change in different ways, over different time scales and at different geographical scales (Parekh and Prajapati, 2015).Environment and societies have always been vulnerable to extreme weather and drastic shift in the distribution of weather patterns. But over the last few decades, evidence is intensifying that distribution of weather patterns are vulnerable to anthropogenic factors as well.In another sense, climate change means the shifting of climatic or meteorological parameters viz. precipitation, maximum temperature, minimum temperature, solar radiation, relative humidity, wind speed etc. and many other factors where as global warming or cooling which refer the changes of the surface temperature (Back and Bretherton 2005).Globally climate change has caught increasing attention in research field due to its direct and indirect impacts on all major sectors, such as hydro-meteorological, ecological, biological and socio-economic sectors (IPCC, 2001, 2007 and 2013). Climate change is a long term process. It has raised as most alarming issue for the whole world. Therefore, quantification of climatic changes has become necessary. Trend analysis is a method to determine the spatial variation and temporal changes for different parameters associated to climate (Swain, et al. 2015). Mann-Kendall (MK) is one of the most commonly used non-parametric tests for detecting climatic changes in time series and trend analysis (Mann 1945; Kendall 1955). MK trend test is a rank correlation test for two groups of observations proposed by Kendall (1955). Mann–Kendall (MK) test is able to suggest the significant trend in hydrological and climatological time-series data (Modarres and Silva, 2007).

For the Indian context there are several works regarding MK test. Jhajharia et al. (2009) showed the analyses of temporal characteristics of pan evaporation using Mann–Kendall test. Burn et al. (2011) did their study on climate change on a local basis and the hydrological trend in total annual precipitation rate on the basis of Mann Kendall (MK) test analysis coupled with the wavelet transformation. Mondal et al. (2012) studied the changing pattern of long term trend of rainfall in Orissa coastal region, India. Patle et al. (2013) did their study on temporal variability in climatic parameters and potential evapotranspiration with the reference of crop from 1981 to 2011. Duhan et al. (2013) studied the spatial and temporal variability in the air temperatures at Madhya Pradesh of India based on monthly, annual and seasonal range from 1901 to 2002 using MK test. They also studied on seasonal and annual trends of rainfall for the Haryana and Madhya Pradesh, India (Duhan and Pandey2013). Jain et al. (2013) did an analysis of rainfall and temperature trends using MK test for northeast India. Sonali and Kumar (2013) studied a spatio-temporal trend analysis using MK test with annual maximum and minimum temperatures of India. Trend analysis namely the Mann–Kendall test and Sen's slope estimator of the mean and extreme annual daily rainfall and temperature at the spatio-temporal level was done for all the 33 urban areas of Rajasthan state of India (Pingale et al. 2014). Suryavanshi et al. (2014) studied the trend analysis of historic past climatic variables using MK test for the Betwa river basin in India. Chaudhuri and Dutta (2014) described a trend of pollutants, temperature and humidity over Kolkata region of India using MK test and

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different ARIMA models. Bisai et al. (2014) used Mann-Kendall test for detection of surface air temperature for weather observation in Kolkata, India. The long term trends of meteorological parameters like precipitation, temperature, solar radiation, wind direction etc. of Western Rajasthan using geographical information system and statistical techniques (Kundu et al. 2015). Roy (2015) detected increasing trends in temperature and decreasing trends in rainfall over Rajasthan during last century and also delay in onset of monsoon resulting increase in post monsoon rainfall. The decreasing annual and monsoon rainfall of India in most of the sub-divisions, and temperature fluctuations were observed in all the places (Mondal et al., 2015). Shrestha et al., (2016) observed trends and changes in daily temperature and precipitation extremes over the Koshi river basin (1975–2010) and the results indicate that the risk of extreme climate events over the basin is increasing, which will increase people's vulnerability and has strong policy implications.

II. Materials And Method

Study area

The current study is carried out over the Maharana Pratap University of Agriculture and Technology (MPUAT) service area Udaipur, Rajasthan, India. MPUAT service area consists of seven districts lying in the south and south-eastern part of Rajasthan. Rajasthan is the largest state with latitude 27.0238°N, and longitude 74.2179°E of India constituting 10.4 per cent of total geographical area and 5.67 per cent of total population of India. It consists of ten agro-climatic zones from which the entire MPUAT service area falls under two agro-climatic zones i.e. sub-humid southern plains & Aravalli hills and humid southern plain. The soil of sub-humid southern plain are lithosols at foot hills and alluvial in plains while humid plain has Predominantly reddish medium texture, well drained calcareous, shallow on hills, deep soil in valleys .Udaipur, Bhilwara, Chittorgarh, Rajsamand districts comes under sub-humid & Aravalli hills and humid southern plain consists of Banswara, Dungarpur, Pratapgarh districts (http://waterresources.rajasthan.gov.in). Over the entire MPUAT service area, the types of climate are also different from one district to another. Udaipur and Banswara districts experiences tropical climate which have a non-arid climate in which twelve months have mean temperature of at least 18°C and average precipitation of at least 60 mm. The climate of Bhilwara and Dungarpur districts have a local steepe climate which is a semi-arid climate having average July temperature ranges from 21 to 23°C and in winter it ranges from -13 and 0°C and an average temperature of 460 mm in north and 260 mm in south. Pratapgarh experiences a temperate climate, it is a subtropical climate with temperature is moderate not so cold and hot where the climate of Chittorgarh district has a dry climate which is a arid climate having average temperature is below 18°C and average precipitation is less than 250 mm throughout the year. MPUAT service area accounts for 22.9% geographical area of the state. There is a sizeable area of 10.58 lac hectare under barren and uncultivable land. About 5.61 lac hectare area is under pasture and grazing land. The size of culturable wasteland is 7.29 lac hectares.

Data used

Monthly precipitation and mean temperature data of seven districts over the period of 30 years (1984-2014) has been downloaded from India water portal site (http://www.indiawaterportal.org). In the present study spatial and temporal variability of both parameters (precipitation and temperature) has been studied at annual and seasonal basis (pre-monsoon, monsoon, post-monsoon and winter) for detailed analysis. Methodology of dividing data into seasonal basis helps in eliminating the effect of seasonality in the time series. For the development of GIS based maps the shape file of MPUAT service area has been collected from NBSS, regional centre, Udaipur, Rajasthan, India.

Mann-Kendell test

In the present study a popular non- parametric method Mann-Kendall test has been used to detect trend in the rainfall and temperature at 5% significance level. Because of non-parametric methods are more suitable to detection of trend rather than the parametric methods in hydro-metrological data (Helsel*et al.* 2002; Hirsch, 1982). Mann-Kendall test is rank based test, used where autocorrelation is not significant and it can tolerate to outliers, distribution free and has higher power than the other test (Duhan and Pandey, 2013). Therefore in the present study Mann-Kendall test is applied after pre-whitening for all meteorological parameters at pre-monsoon, monsoon, post- monsoon to eliminate the effect of autocorrelation in the data series (Von Storch, 1995; Partal and Kahya, 2006; Mohammad and Jha, 2014). The standardized Mann-Kendall test Z value for computation of statistical significance of trend in the time series is given as follow:

$$Z = \begin{cases} \dfrac{S-1}{\sqrt{Var(S)}} & \text{if } S > 0 \\ 0 & \text{if } S = 0 \\ \dfrac{S+1}{\sqrt{Var(S)}} & \text{if } S < 0 \end{cases}$$

Where S is the statistic value, which possesses normal distribution for large number of sample size (Kendall, 1975) and can be computed as;

$$S = \sum_{k=1}^{n-1} Sgn \, (x_j - x_i)$$

Where,

xi is ranked from i = 1, 2, 3 … n -1

xj is ranked from j = i + 1, 2, 3 … n in the time series.

The values of +Z and –Z indicates upward and downward trend respectively. The Z values of Mann-Kendall test accept the null hypotheses of no trend when ± Z ≤ Z1-x/2, where x is the level of significance at two tailed trend test. In the present study test will be carried out at 5% significance level, therefore when Z value exceeds ± 1.96 null hypotheses is rejected and show the existence of trend in the series.

Inverse Distance Weighting Method (IDW)

It is a type of deterministic method for multivariate interpolation with a known scattered set of points. The assigned values to unknown points are calculated with a weighted average of the values available at the known points. Distance Weighting (IDW) is based on the assumption that the nearby values contribute more to the interpolated values than distant observations. In other words, for this method, influence of a known data point is inversely related to the distance from the unknown location that is being estimated. The advantage of IDW is that it is intuitive and efficient. This interpolation works best with evenly distributed points.

III. Results And Discussion
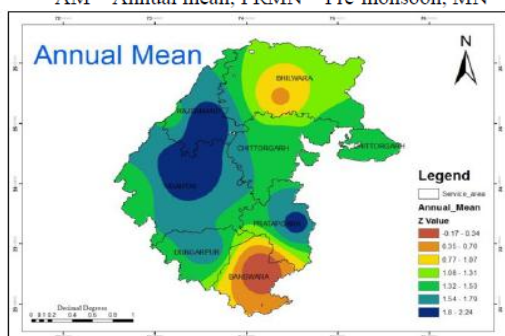
Trends in precipitation

Spatial distribution of annual mean, pre-monsoon (April, May and June), monsoon (Jul to September), post-monsoon (October and November) and winter season (December, January and February) of precipitation for the 7 districts of MPUAT service area are plotted in GIS based maps by using IDW method.

**Table 1** Mann Kendell Z value for Rainfall for the period 1984-2014

S. No.	Name of the District	Man Kendell Z value for rainfall for 1984-2014				
		AM	PRMN	MN	POMN	WN
1	Udaipur	2.24	0.49	2.02	0.97	-0.13
2	Bhilwara	0.68	0.49	0.37	-0.23	0.55
3	Chittorgarh	1.46	0.36	1.53	-0.58	0.02
4	Rajsamand	2.12	-0.09	1.48	1.5	-0.84
5	Banswara	-0.17	-0.39	-0.12	-0.52	0.49
6	Dungarpur	1.67	0.05	1.67	-0.14	1.1
7	Pratapgarh	1.87	0.39	1.77	-0.48	0.12

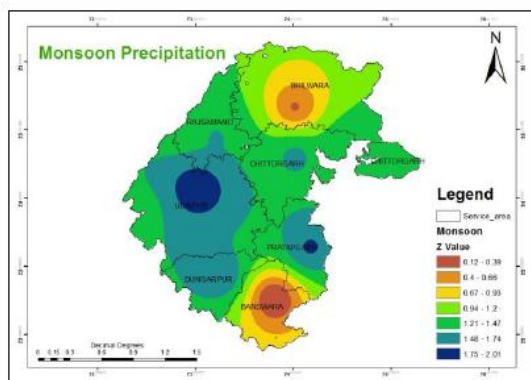Note: - 1.96<Z< 1.96 = No trend, Z>1.96 = Increase in trend, Z< -1.96 = Decrease in trend.

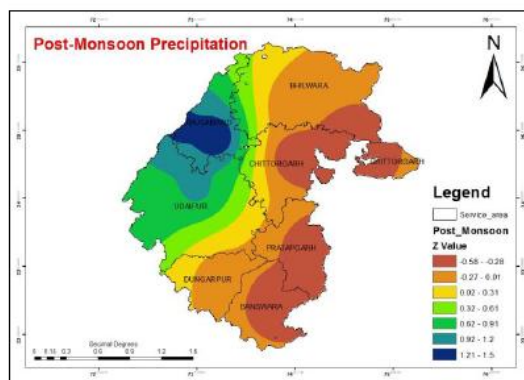AM – Annual mean, PRMN – Pre-monsoon, MN – Monsoon, POMN – Post-monsoon, WN – Winter.

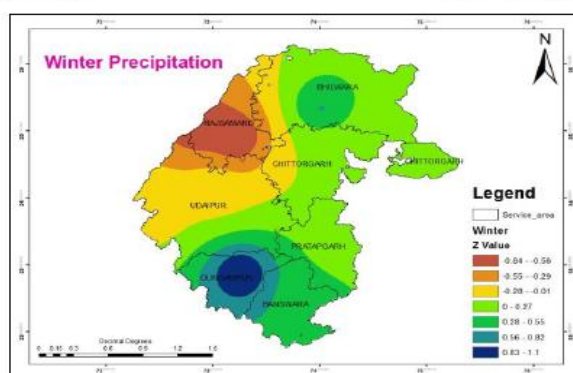**Fig 1.1: Mann-Kendell Z value for annual mean precipitation**
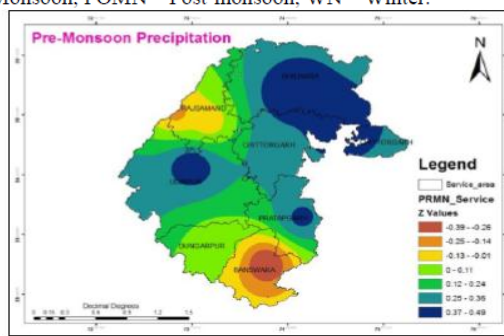
Fig 1.2: Mann-Kendell Z value for pre-Monsoon precipitation

Fig 1.3: Mann-Kendell Z value for Monsoon precipitation

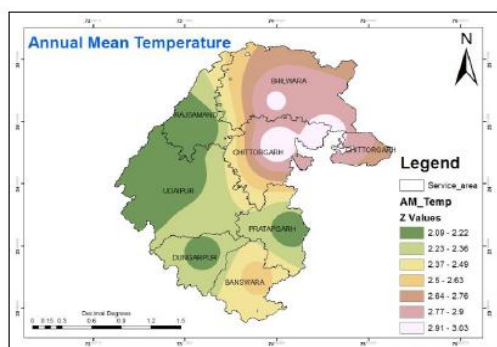Fig 1.4: Mann-Kendell Z value for post-Monsoon precipitation

Fig 1.5: Mann-Kendell Z value for winter precipitation
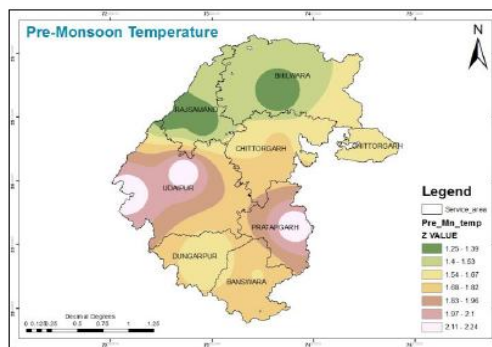
Trends in temperature

Like precipitation the trend of temperature is also calculated by using the non parametric Mann Kendell test for Annual mean, pre-monsoon, monsoon, post-monsoon and winter. The average temperature is used for the calculation. The calculated trend has been plotted in GIS based maps by using IDW method.

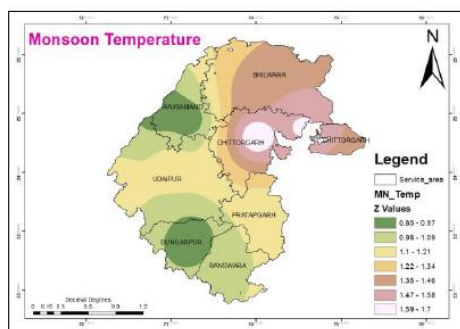**Table 2** Mann-Kendell Z value for temperature from 1984-2014

| Sr. No	Name of the district	Mann Kendell Z value for temperature for 1984-2014				
		AM	PRMN	MN	POMN	WN
1	Udaipur	2.14	2.24	1.14	1.09	2.07
2	Bhilwara	2.92	1.26	1.43	1.87	2.65
3	Chittorgarh	3.03	1.7	1.7	1.5	2.31
4	Rajsamand	2.11	1.29	0.88	1.19	2.38
5	Banswara	2.55	1.67	1.09	1.36	2.38
6	Dungarpur	2.18	1.56	0.85	1.16	2.14
7	Pratapgarh	2.12	2.2	1.11	1.01	2.02

Fig 2.1: Mann-Kendell Z value for annual mean temperature

Fig 2.2: Mann-Kendell Z value for pre-Monsoon temperature

Fig 2.3: Mann-Kendell Z value for Monsoon temperature
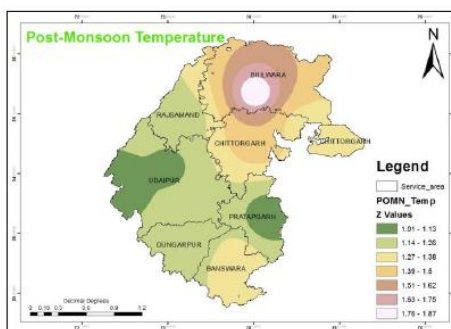
Fig 2.4: Mann-Kendell Z value for post-Monsoon temperature
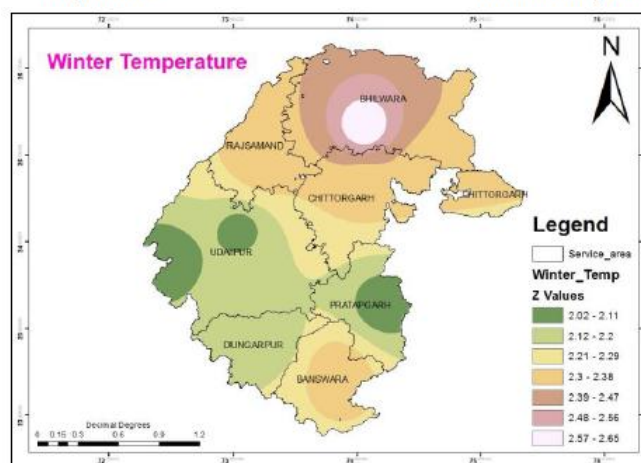
Fig 2.5: Mann-Kendell Z value for winer temperature

IV. Conclusion

The present study is carried out to examine the spatial and temporal variability and trends in precipitation and mean temperature at annual and seasonal basis for seven districts of MPUAT service area, Rajasthan, India.The mean annual rainfall has an increasing trend for the Udaipur and Rajsamand districts where there is no trend for other districts. For seasonal basis there is a no trend for pre-monsoon season for all the seven districts under the study region. Only Udaipur district showed a higher trend for monsoon season and other districts has no trend for the same period. For post-monsoon and winter seasons there is always no trend for all the seven districts under the study area. There is a higher trend in temperature at 5% significance level for annual temperature at all 7 districts of the study area in the period of 1984-2014. The decrease in trend is found in the pre-monsoon, monsoon and post-monsoon seasons on seasonal basis. The increase in trend for annual mean temperature increases with latitude and also increases with decrease in vegetation density in the study area.

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